# Space Shuttle Processing Simulation Model

# **Macro Level Simulation Model**

## Space Shuttle Processing

between the Kennedy Space Center and the University of Central Florida Developed under a NASA Space Act Agreement



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20

▼ The simulation model encompasses the existing space shuttle ground processing Facilities, Ground-Support Equipment (GSE) infrastructure and Flight-Hardware elements to the level of detail that NASA retains management responsibility for; such as...

 Crawler/Transporter	MLPs	SRM/SRB
 ET Transporter	VAB	External Tanks
Engine Hyster	Engine Shop	SSMEs
 Orbiter Transporter	OPF	Orbiters
GSE	Facilities	Flight Hardware

- The simulation model logic is consistent with current Space Shuttle program ground rules and constraints such as..
- After 8 flights, the shuttle orbiter undergoes depot level maintenance (OMDP/OMMP) in California.
- only one shuttle on orbit at any given time.

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### USA - Manifest Planning - C. Downs, 1-6693 NASA - J. Angermeer, P.Z.-F., 1-9215 10 December, 1999 KSC Flight Hardware Quicklook can be viewed on the Web at: http://wsego1.ksc.nasa.goulusago/orgs/flipc/pmfrinde1.htm OV-102 FRC2 | LP05 | RP05 HMF - OMS/RCS Processing Area **RP03** RPOR RP01 AT OPF AWAITING INSTL'N. SRB/FWD Assemblies temporary storage INSTALLED IN ORBITER IN TEST CELL (Non-Hazardous Work) RFA STS-92 OV-103 2 IN TEST CELL (Critical Path Testing) 5 LP03 IN STORAGE CELL OV-103 FRC3 OV-104 FRC4 OV-105 FRC5 STS-101 0.4.104 ROLLOUT: 12/13/99 High-Bay 1 High-Bay 2 STS-98 OV-104 OV-105 RFC RAC RAB D STS-101 U ROLLOUT 2/21/00 ET/SRB MATE: 2/13/00 ET-184 High-Bay 3 High-Bay 4 Bary 1 Bay 2 S15-97 OV-105 LAB 04.304 OV-104 Orbiter Processing Centers ROLLOVER VAB HB-3: 15 FEB 00 := KSC Flight Hardware Quicklook/STS Mainline Facilities Refurb/Parksite (West) Refurb/Parksite (East) KSC(SLF) / DFRC STS-98/DV-104 FB HFW RSPM 76-SPB BIO104 S15-92/OV-103 FR HW PSRW 75-5RB BIO102 STS.97/0V-105 FR HW RSAM 72-SA8 810103 \$75-101 Bay 3 RA RAC Pad RSPM 73-SPB BR399 HB1 RSRN 71-SRB BIO100 STSTOT/OV-LOAFE HW RSEM 74-SER BROTOT (Inspection Stands) aunch Pad 39A (spue)S Roberts Road Site South LAB East RPSF ( \$75-97) RFC RAB North LAUNCH: 12/16/99 TIME: 2118 EST RPSF Surge 2 (315-101) (515-0) RFC RAC RAB OV-102: Cofumbia - # Palmdale OV-103: Discovery OV-104: Atlantis OV-105: Endravour نشا ئىيد Launch Pad 398 RPSF Surge 1 (STS-92) Suspect (Railcars) (STS-98) LAC 1

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### Descent Phase RTLS) Core Phase.A Phase-B Start of Ground Ops Flow Flight 2 Intact Abort Remove from SCA Mate to SCA Ascent Phase Launch Day Remove Ferry Flight from SCA Palmdale to KSC Ferry Flight KSC to Palmdale SRB A MLP (VAB) MLP MLP (Pad) Slacking Preps Park Site Ops Post Launch Ops Press to MECO ATO (AOA) TAL Scrub Fwd Skirt Descent Phase RSRM / SRB Flow Mate to SCA Nominal RTLS Descent On-Orbit Phase Aff Skirt Turnaround (ARF) RSRM Segment Raii RSRM Turnaround (UTAH) Segments to Utah Flow Post-Palmdale OPF Flow VAB SSV SRB / SRM Fwd Assy Stacking (VAB) Buildup (ARF) Nominal Descent Stay up 1 extra day OMS Pods OMDP (HMF) ET Transport ET Check-out ET Male & Dr KSC (VAB) Close-out (VAB) Aft Booster Buildup (RPSF) Normal OPF Flow OMS Pods Turnaround (HMF) SSME Turnaround (Engine Shop) Pre-Palmdate OPF Flow KSC Chosen Rail RSRM Segments to KSC Land at TAL Site DFRC Chosen Officed & Segment Inspection (RPSF) Segment Storage in Surge (RPSF) 8th Flight? Descent Phase -Yes-Descent Phase TAL Site Land at KSC ET Manufacturing Mate to SCA -- Processing flows in OPF, VAB etc. Land at KSC Model Outputs - Expected Flight Rate - Facility & Flight H/W Utilization % -- Launch Day results -- Landings at KSC or DFRC -QRAS, PRA etc. for flight events Ferry Flight TAL Site to KSC Model Inputs Historical data for: DFRC Turnaround Ferry Flight DFRC to KSC Remove from SCA Land at DFRC Mate to SCA

### Flow Diagram "ST Day 2000: Reducing Risk for the Next Generations" - Space Shuttle Processing Space Shuttle Processing Simulation Model

## Utilized commercial off-the-shelf Software

Rockwell Software\* Arena \*Systems Modeling

Simulation Software

Microsoft Project Microsoft Excel Microsoft PowerPoint

Microsoft Visio

Project Schedule

Data Files

Knowledge Files & Presentations

Flow Diagrams

Averill M. Law &

Associates, Inc. ExpertFit

Distribution Fitting

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# Space Shuttle Processing Simulation Model

"Normal" ODE Flore	I I OCCESS E COCALION	File	Process Title	Process Location	File
	OPF	OPF Flow.ppt OPF UCF TA Days.xls	SRB Retrieval	Atlantic Ocean	SRB Retrieval.ppt
VAB SSV Flow	VAB Integration Cell	VAB SSV Flow.ppt VAB SSV TA Days.xls	SRM / SRB Disassembly & Inspection	Hangar AF	SRB Safng Disassy.ppt
Pad Flow	Launch Pad	Pad Flow.ppt Pad Flow UCF.xls	Б	Utah Rail Roads	RSRM.ppt RSRM Transit Time.xls
Launch Day L	Launch Pad	Launch Day.ppt	Rail RSRM Segments to Utah	Rail Roads	RSRM KSC Time.xls
- Post	bed dome	Launch Data.xls Scrub Flow.ppt	SRB Subassembly Turnaround Cycle	ARF	SRB ARF.ppt SRB ARF Data.xls
		Launch Data.xls Ascent.ppt	RPSF Operations	RPSF	RPSF.ppt SRB Aft Booster Bld Up.xls
Ascent Phase / Intact Abort Scenario's		SAIC Midterm Abort.ppt	SRB/SRM Stacking	VAB Integration Cell	SRB Stacking.ppt
		Risk PRA.xls	ET Manufacturing	Michond, LA	ET Manufacturing.ppt
On-Orbit Phase	LEO	On-Orbit.ppt	ET Transport to KSC	LA to FL	ET Manufacturing.ppt
		On Orbit UCF.xls On-Orbit.ppt	ET Checkout	Checkout Cell	ET Ck-Out TA Days.xls
		Landings.xls KSC Landing ppt	ET Mate & Closeouts	VAB Integration	ET Check Mate.ppt ET TA Days xls
Land at KSC S		Landings.xls	SSME Turnaround	OPF, VAB, Pad,	SSME UCF Phase B.ppt
Land at DFRC F	Edwards Air Force Base, CA	DFRC Landing.ppt Landings.xls	(O	Engine Shop	SSME Data.xls OMS Pods & FRCS.ppt
Land at TAL Site	Spain or Africa	TAL Landing.ppt	Contingency Turnaround OMS Pods & FRCS OMDP	Livin	HMF History.xls
	Launch Pad, MLP MLP UCF Ph	MLP UCF Phase-	Flows	HMH	HMF History.xls
Platform (MLP) Life F	Park Site, VAB	MLP TA Days.xls	Orbiter OMDP	OPF, Palmdale	Orbiter OMDP.ppt Omdpflows UCFrev A.xls

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### Post-Palmdale OPF Flow VAB SSV Flow OPF Flow SSME Turnaround (Engine Shop) Normal Pre-Palmdale OPF Flow 8th Flight? at KSC Land

Initial modeling assumptions and subsequent changes:

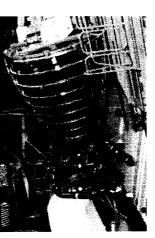
- The engine set (3 engines) stays together. (Changed to allow engines to be separated in the engine shop
- engine. (Changed to 21 engines or 7 sets to more closely reflect 1992-1997 •There are 13 engines and thus four sets of engines plus one ready spare time-frame)
- The engine shop can process one set of engines at a time. (Changed to any number of engines at a time)
- •Any engine set can go in any orbiter on a first need, first served basis.
- Engine removal during a Pre-Palmdale OPF Flow is modeled the same as Normal OPF Flow,

SSME related portions of Diagram at left is the the model.

modeling standpoint is: Of interest from a

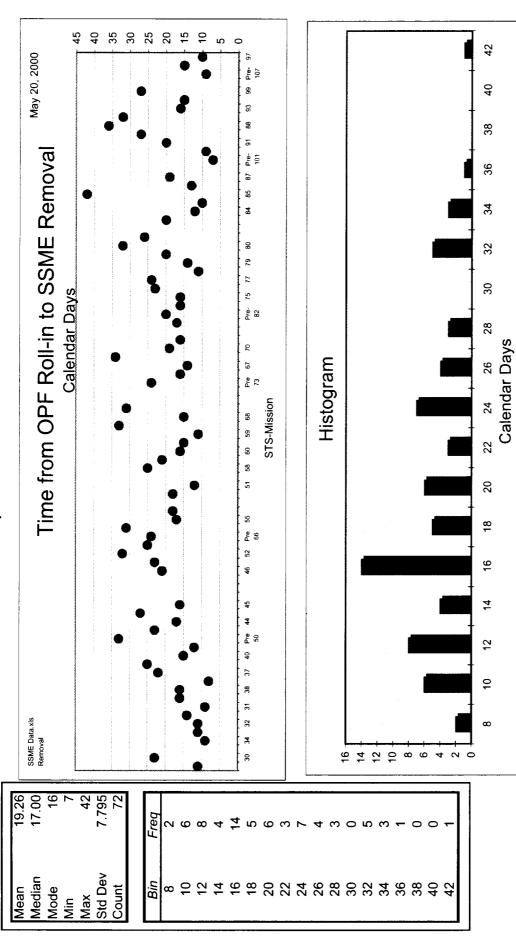
- ·How long from OPF roll-in to SSME removal.
- Travel time between OPF and Engine Shop.
- Duration of Engine Shop activity.
- engines-out and engines-in. Minimum time between
- nstallation and OPF roll-out. Duration between SSME





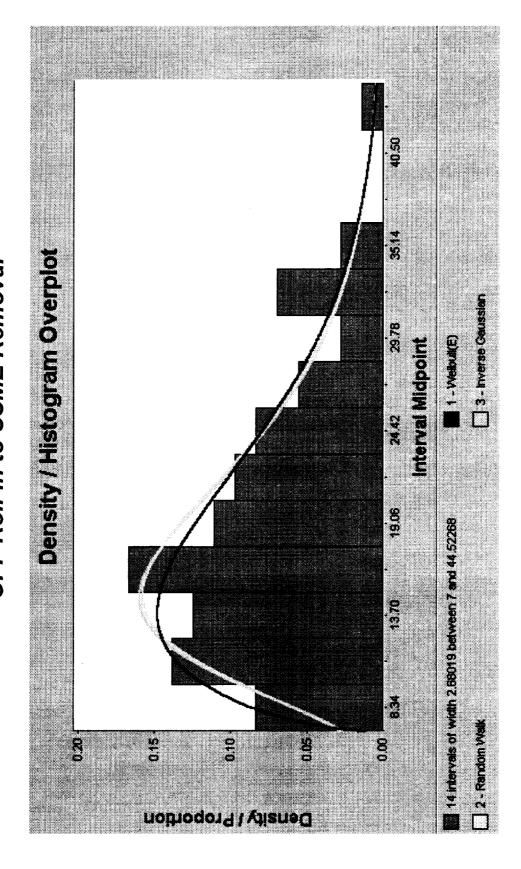
Space Shuttle Processing Simulation Model Knowledge Acquisition Excerpts from Introductory Briefings "ST Day 2000: Reducing Risk for the Next Generations" - Space Shuttle Processing

### Example of historical data



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Example of Probability Distribution Selection using ExpertFit: OPF Roll-in to SSME Removal



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operations now exists and can be used for several applications: A functional probabilistic based simulation of space shuttle

### Analysis of present Space Shuttle System

- Identify Facility & Flight Hardware Utilization percentages
- Identify potential bottlenecks

### Flight Rate Experiments

 Manipulate process-duration probability distributions to achieve 10 (or more) flights per year and analyze model outputs.

## What-if questions can be analyzed such as:

- What is the expected impact on flight rate given the loss of a launch
- What is the expected impact on flight rate given the loss of one VAB Integration Cell?
- detail to be modeled for system specific operational processes or The current model offers an architecture that allows lower level

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Model Applications in current Shuttle Environment Space Shuttle Processing Simulation Model

### The existing model can serve as a First Generation RLV baseline for comparison

- Aid in understanding and serve as a point of departure for new reusable Space Launch Initiatives
- New RLV specific models can be used to increase insight into reusable launch vehicle turnaround, operational processes and business case closure risk.
- Demonstrate Flight Rate dependence on such factors as the RLV architecture, probabilistic processing times, launch scrubs, and ascent outcomes.
- Provide the government with a tool for analyzing and comparing competing architectures
- Requires that each architecture be modeled using similar methodology.

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